



## Optical Measurements in Furnaces as Diagnostic Tool for Combustion Processes in Power Plants

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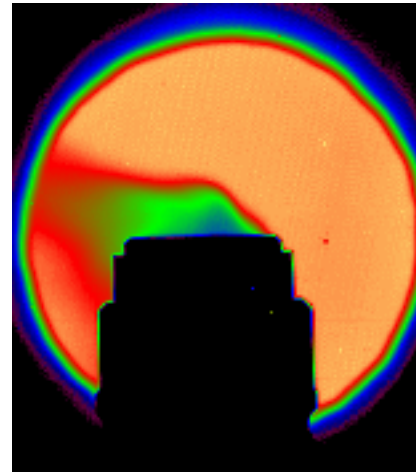
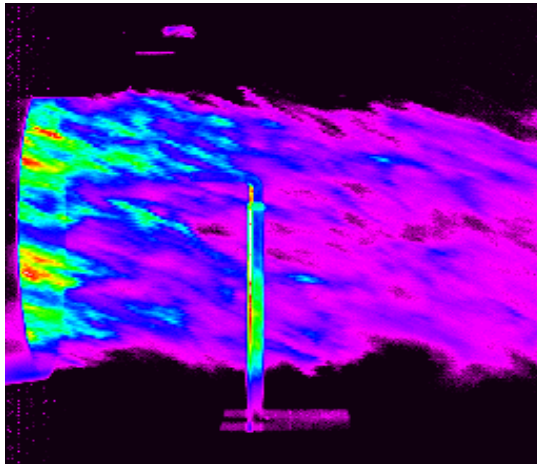
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# Optical Measurements in Furnaces as Diagnostic Tool for Combustion Processes in Power Plants



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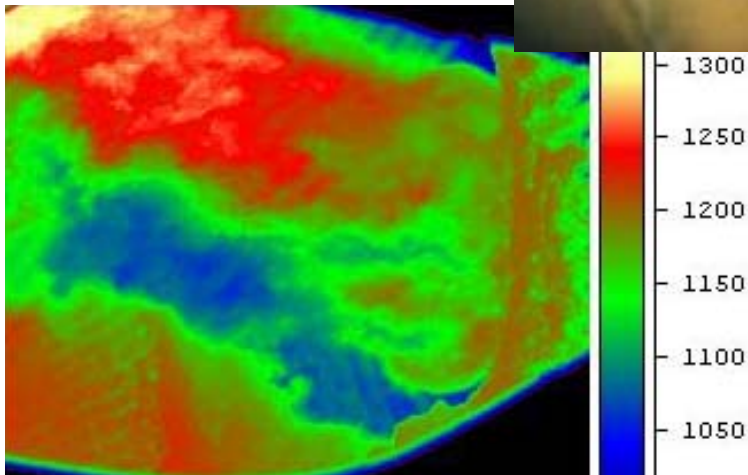
# Optical Measurements



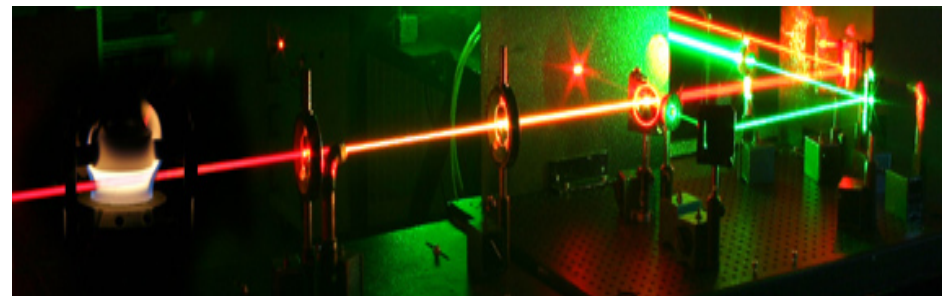
- Short measurement time
- Non-contact
- Multi-parameters
- ...



- Optical access
- Strong absorption
- Complex equipment
- Clean window
- ...



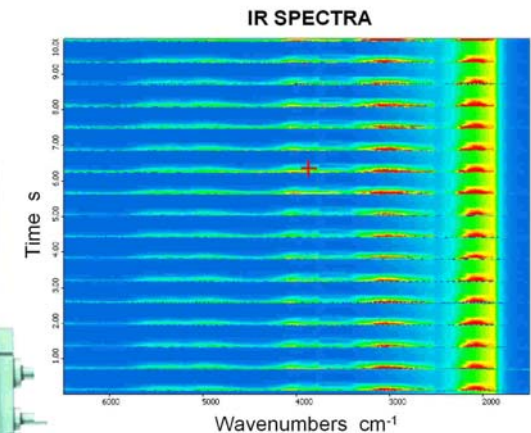
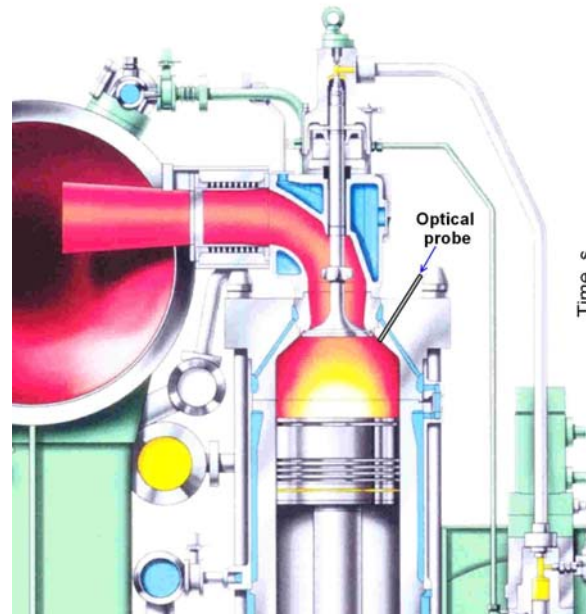
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# OPTICAL MEASUREMENTS

Research and development of optical methods....  
Improve, optimise existing and new combustion  
processes, R&D new energy technologies, etc.

- POWER PLANTS
- ENGINES
- STEEL, INSULATION
- PROCESS INDUSTRY
- R&D NEW ENERGY
- ENVIRONMENT
- etc.



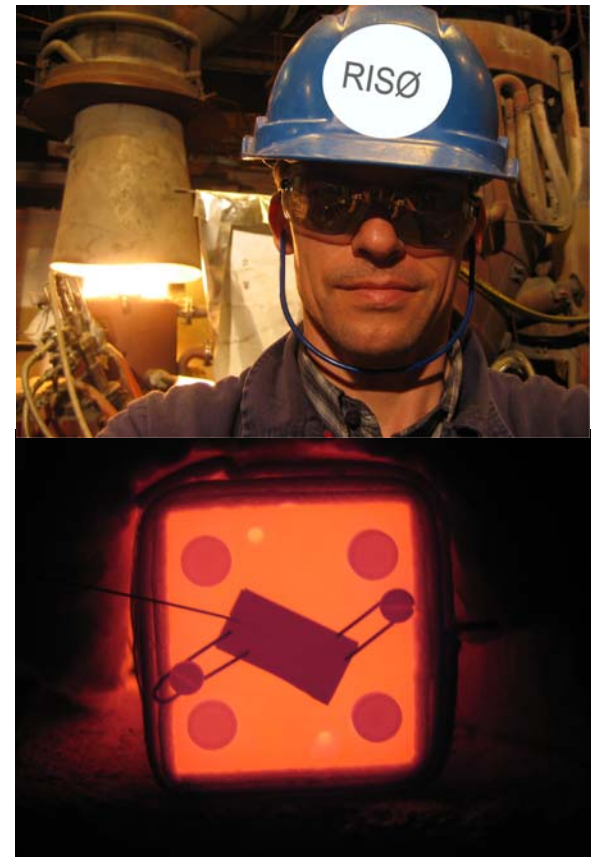
**CORE: TEMPERATURE**



# OPTICAL DIAGNOSTICS?

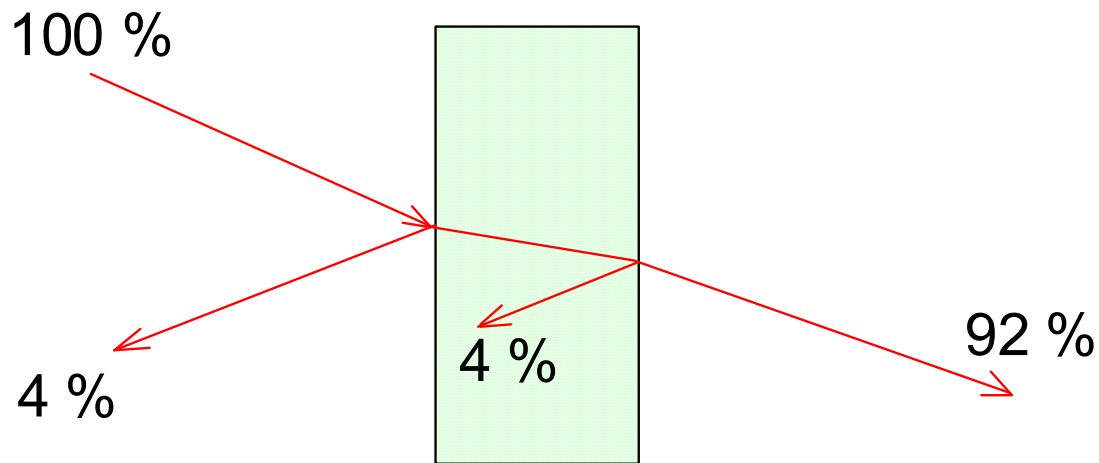


- TEMPERATURE, HEAT FLUX, ...
- GAS COMPOSITION
- PARTICLE SIZE,
- VELOCITY
- EMISSIVITY of SURFACES
- IMAGING, VISUALISATION,...
- DEPOSITES, LEAKS,...
- SENSORS

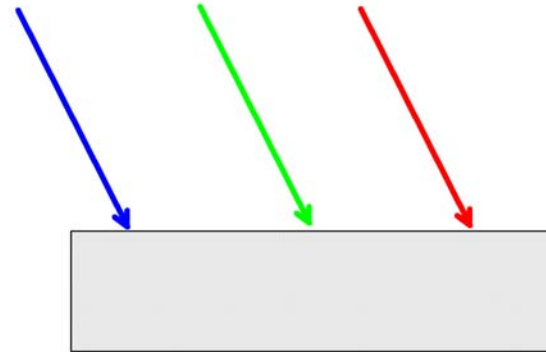
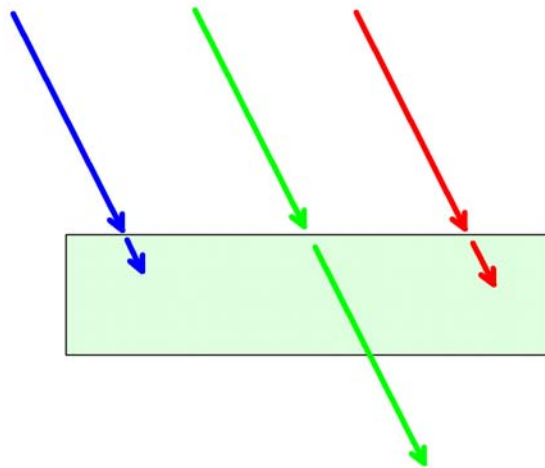


# Properties of Light

$$t + r + a + s = 1$$



# ABSORPTION

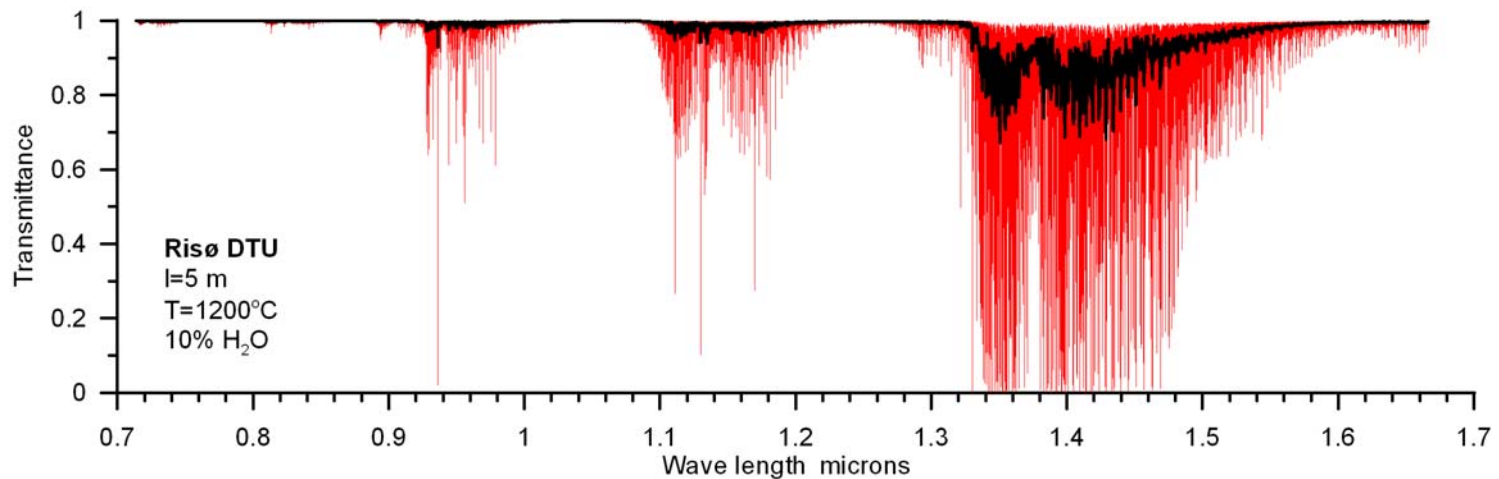
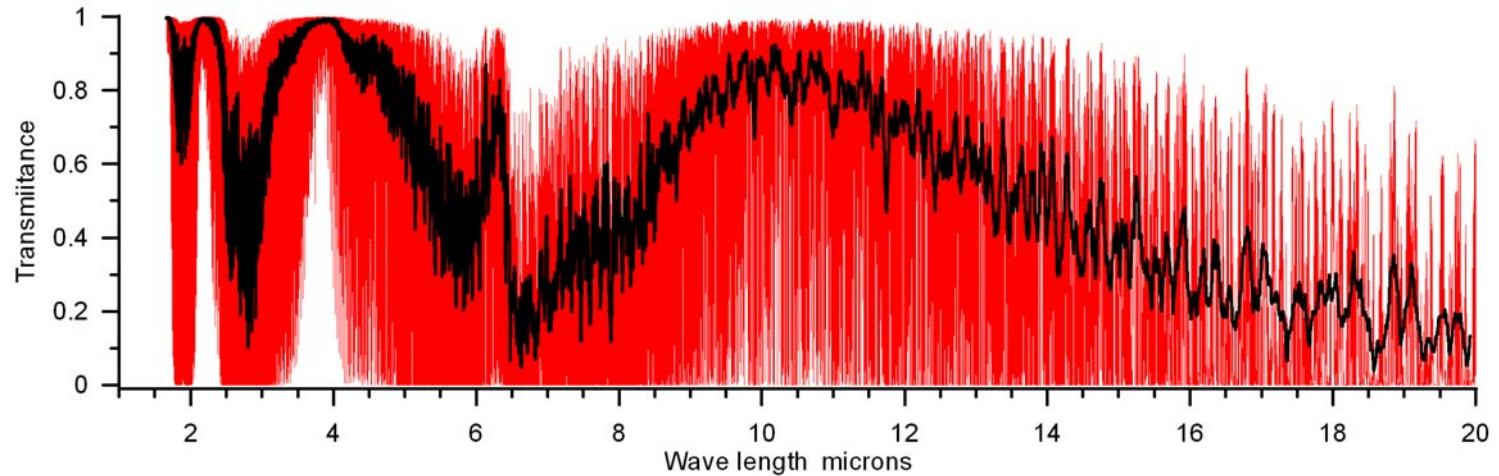


Beer's Law:

$$I = I_0 e^{-abc}$$

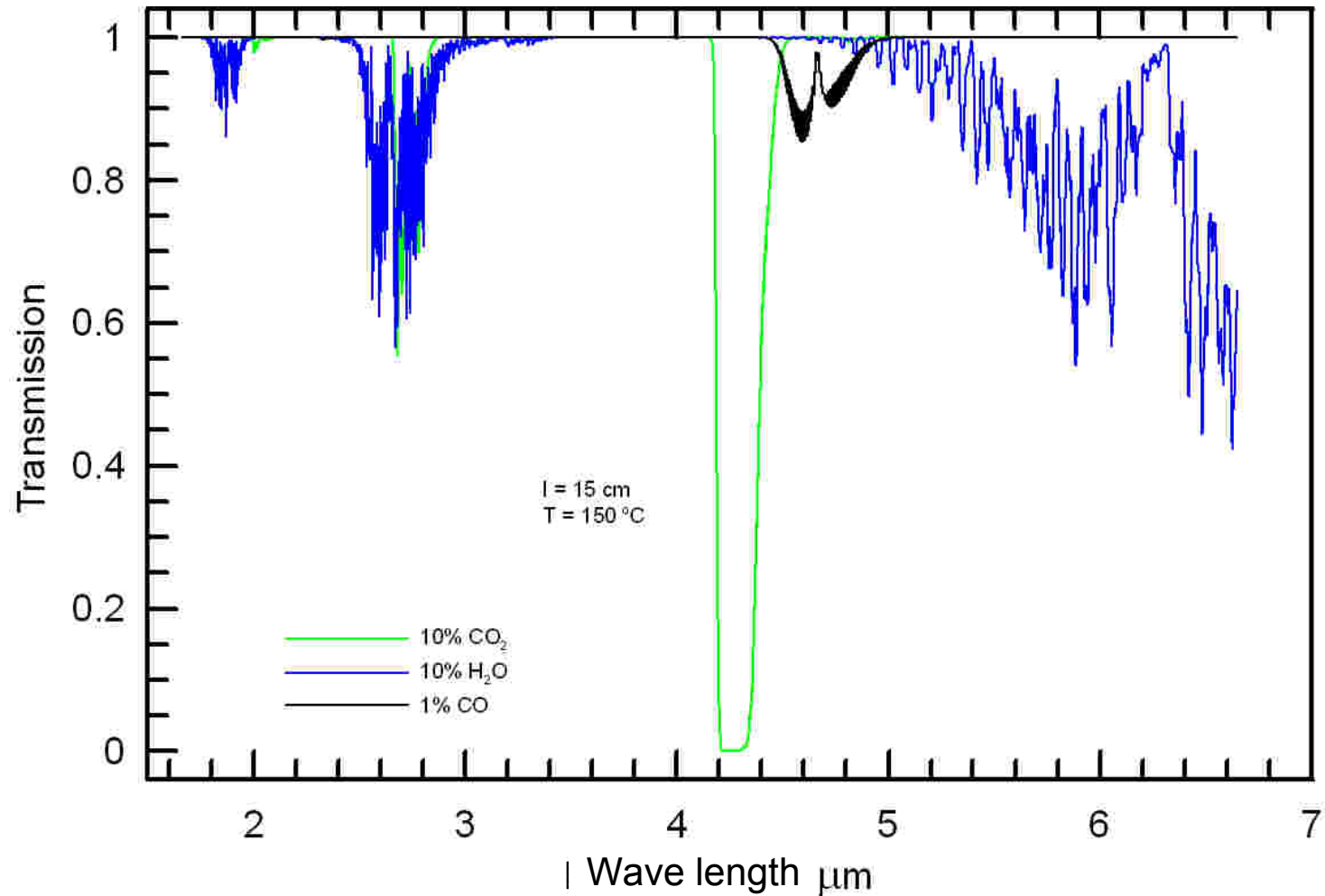


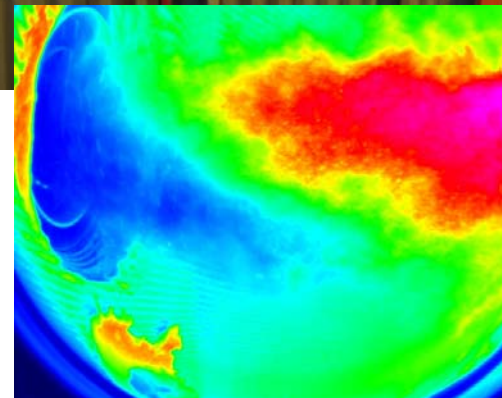
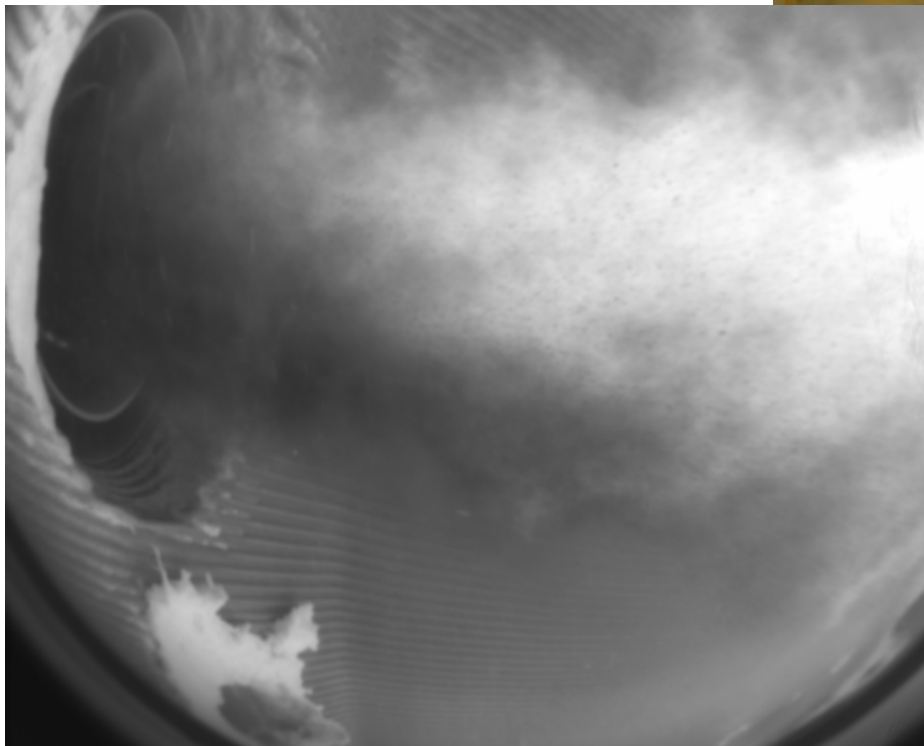
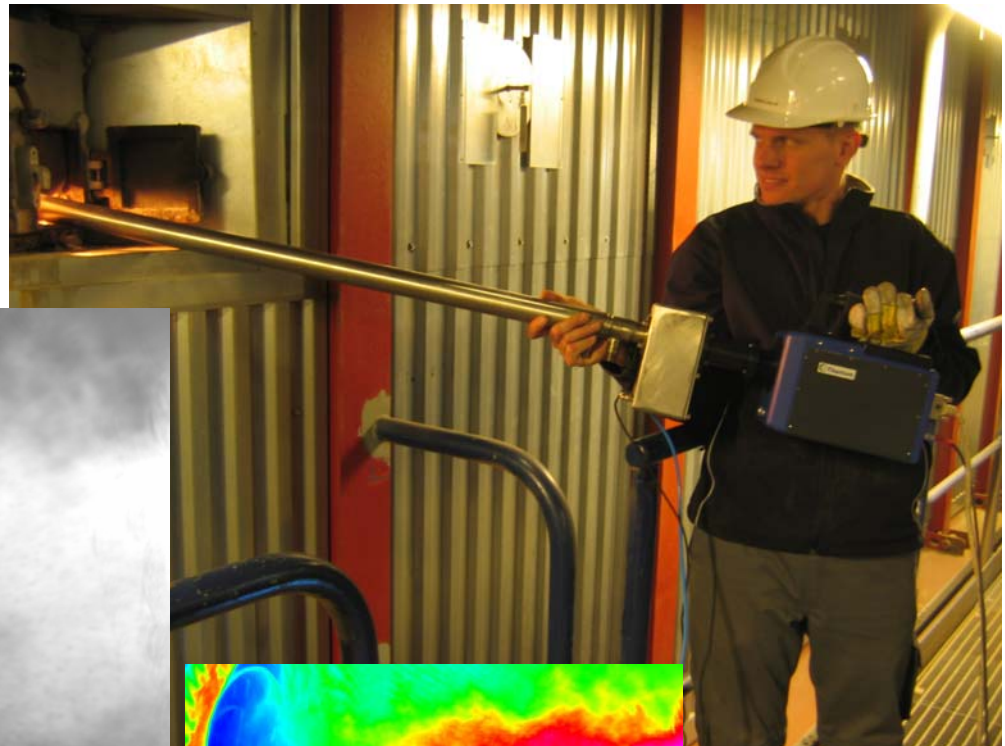
# Absorption water





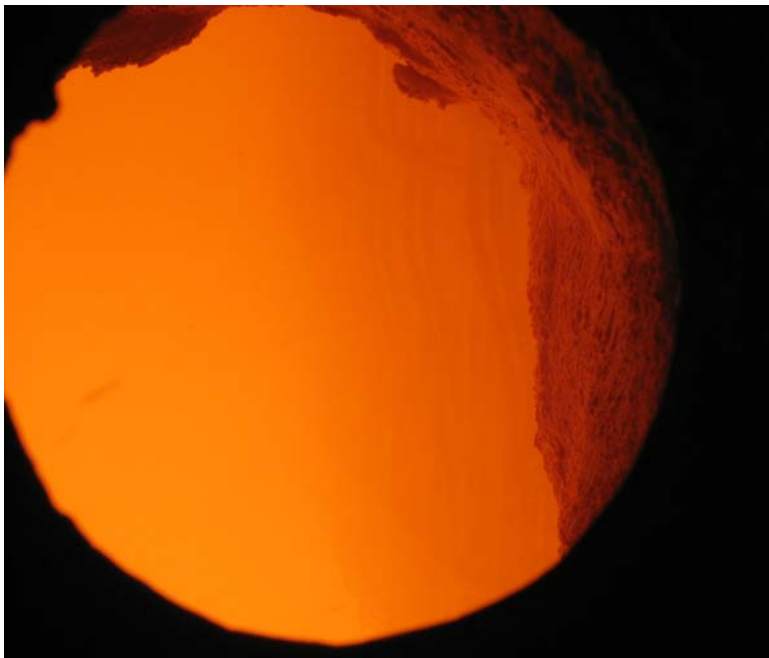
# IR absorption flue gas



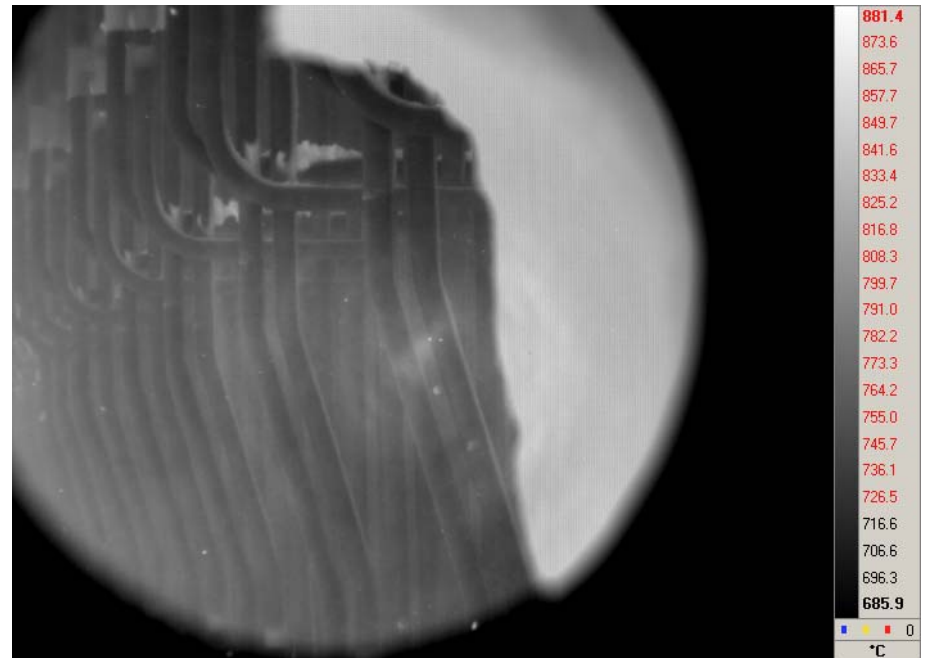


# VIS versus IR

## SUPER HEATER FYNSVÆRKET

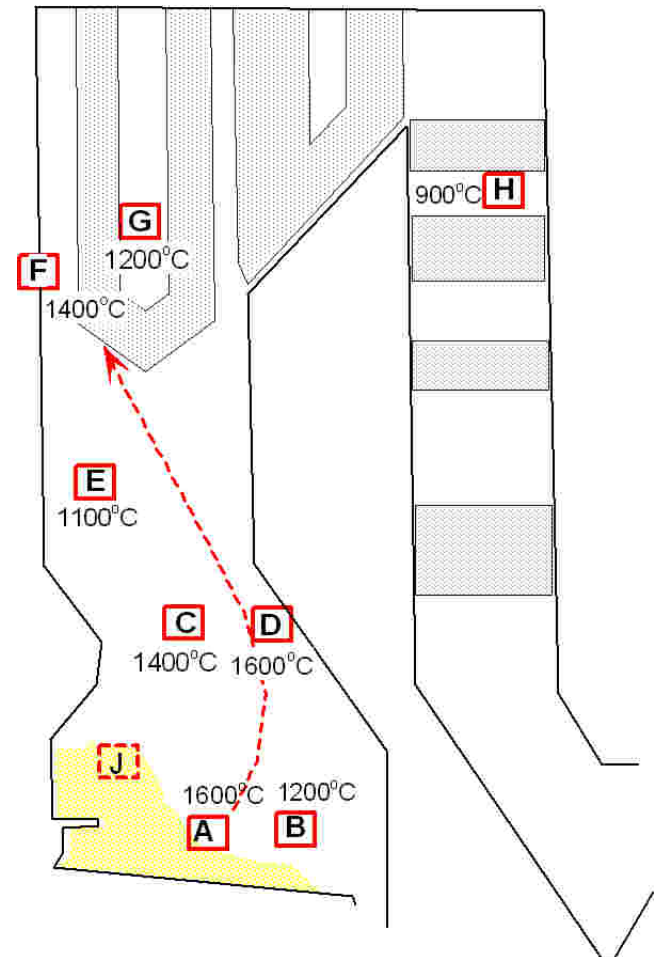
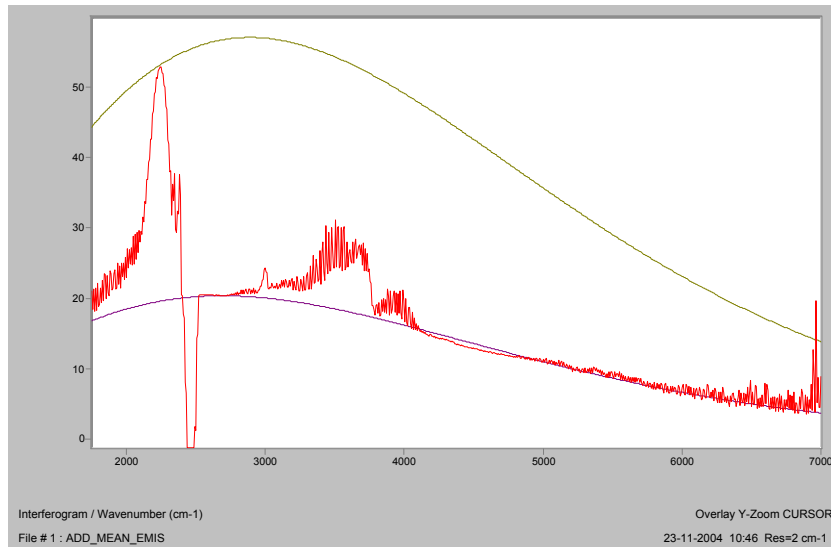
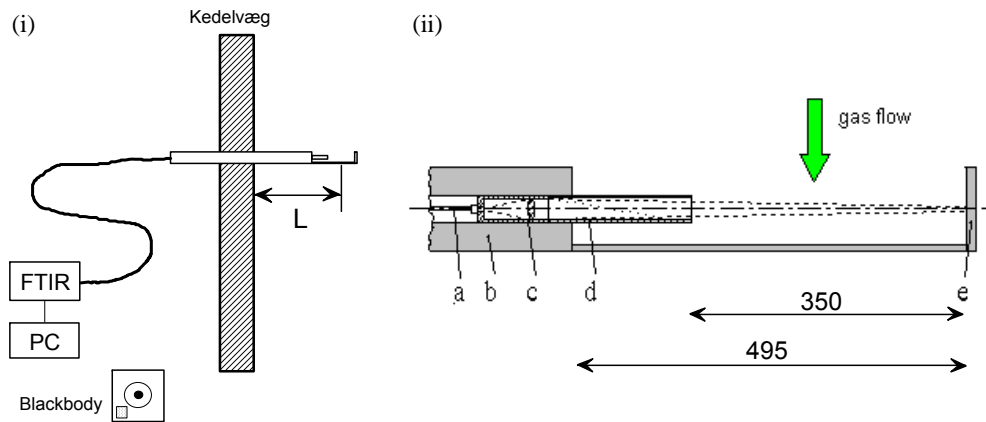


VIS / VIDEO

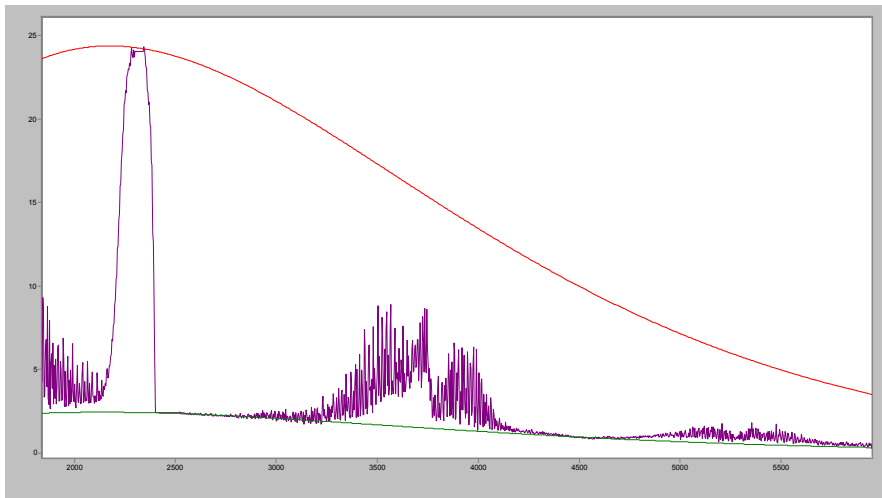


IR

# IR SPECTROSCOPY POWER PLANT



# FTIR Fiber-Optics



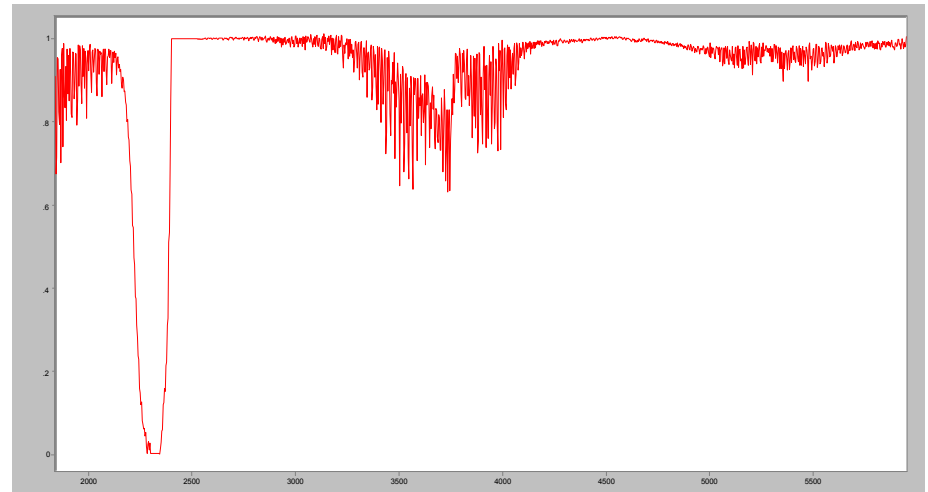
Emission spectrum:

GB: 816.9°C,  $\epsilon=0.106$

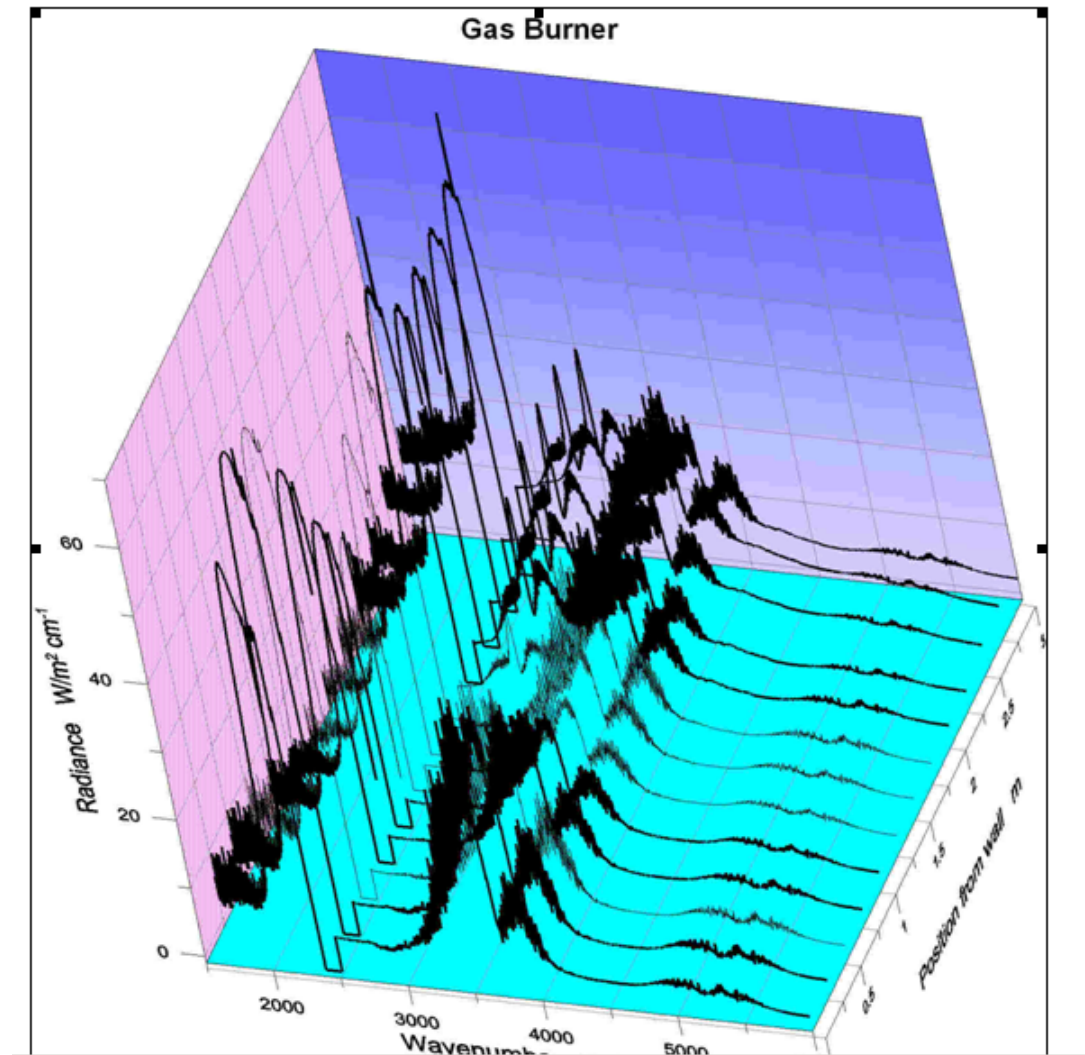
Blackbody curve at 836.0°C

Transmittance spectrum

CO<sub>2</sub>, H<sub>2</sub>O, CO, C<sub>x</sub>H<sub>y</sub>, ...



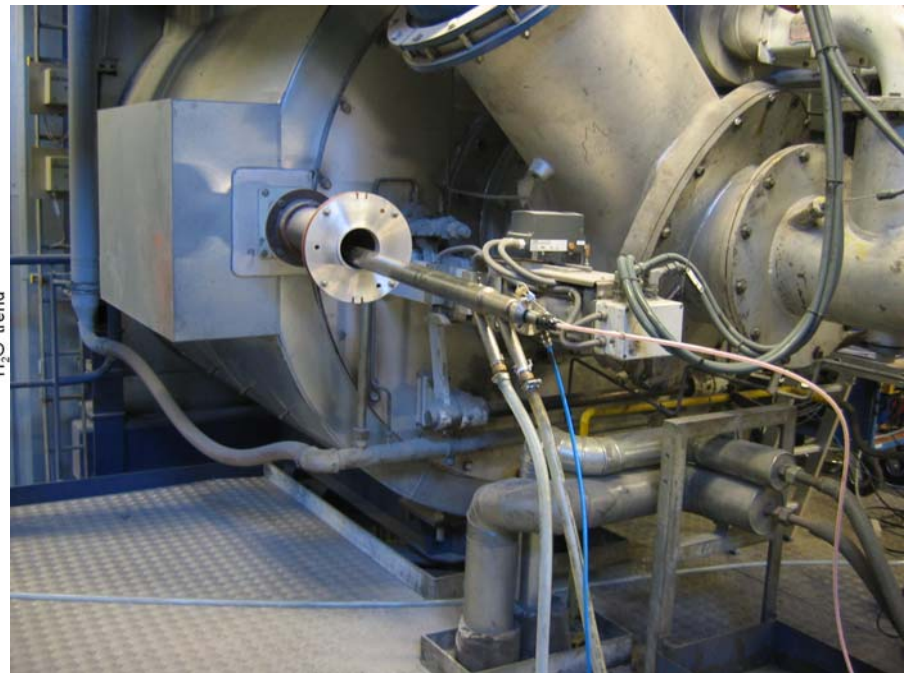
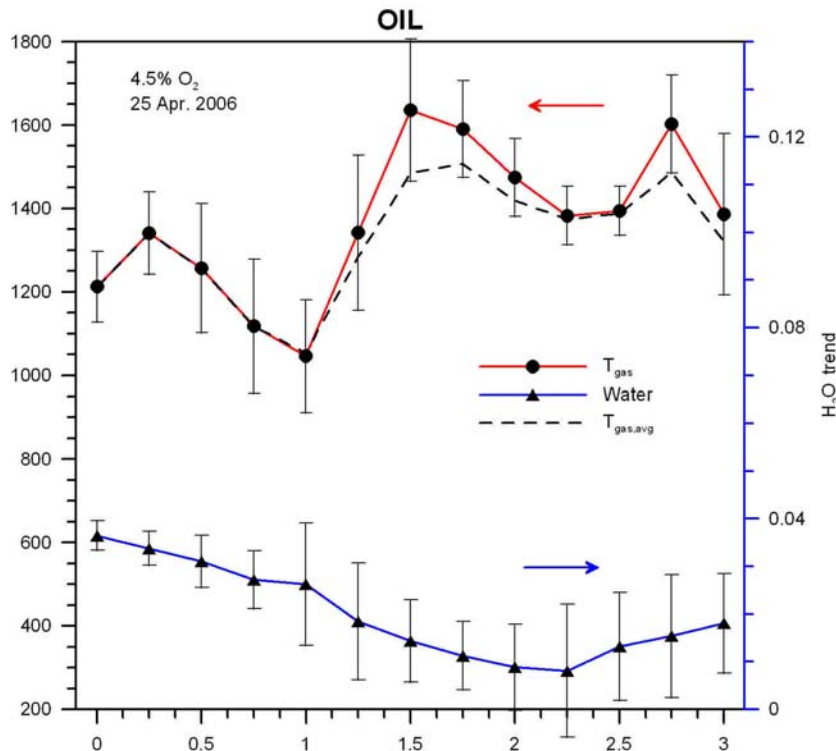
# IR spectra



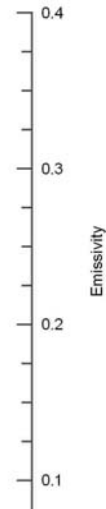
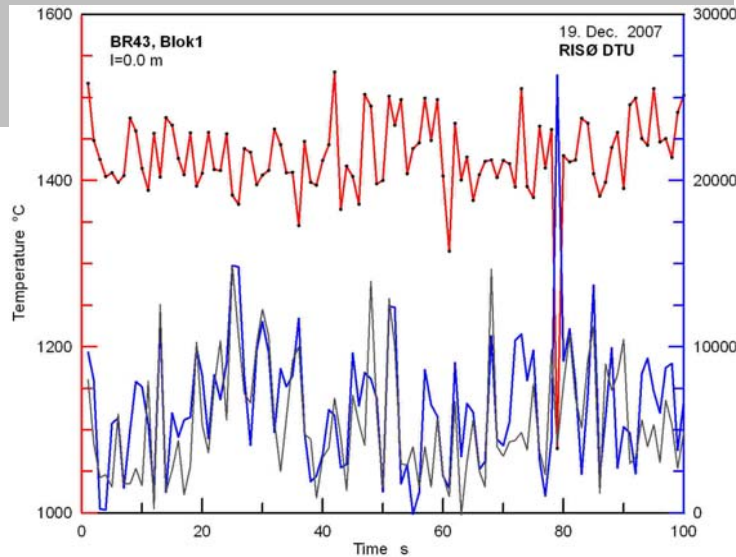
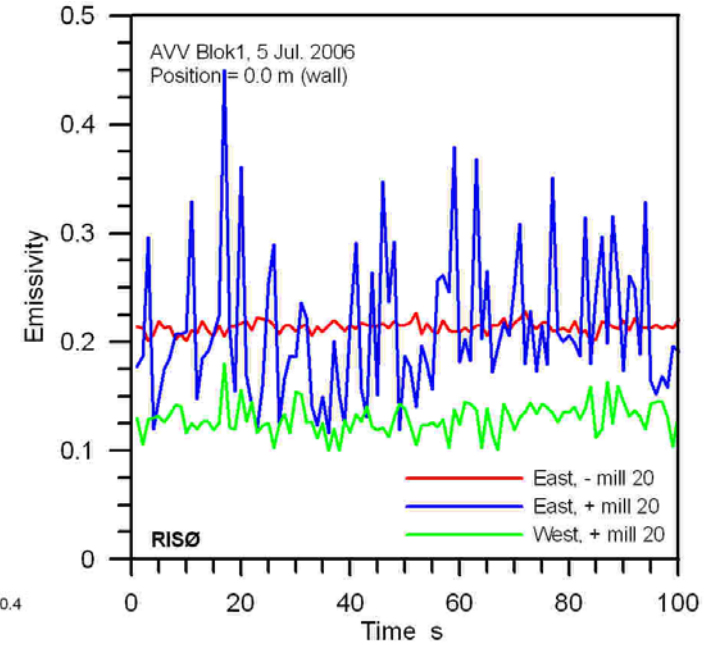
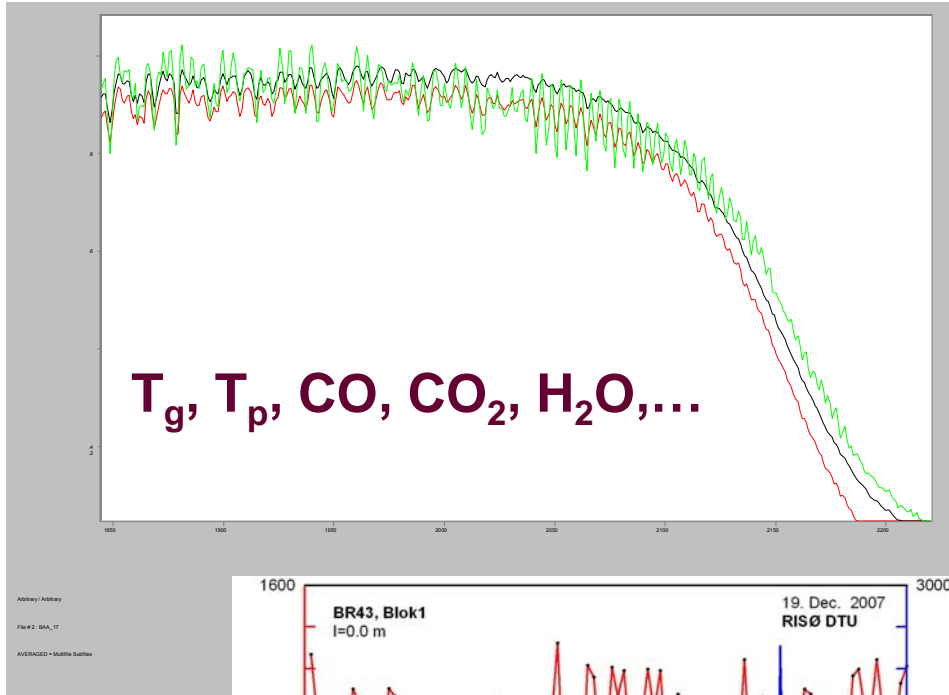


Simultaneously  
temperature and concentration

VERIFICATION  
methods and results

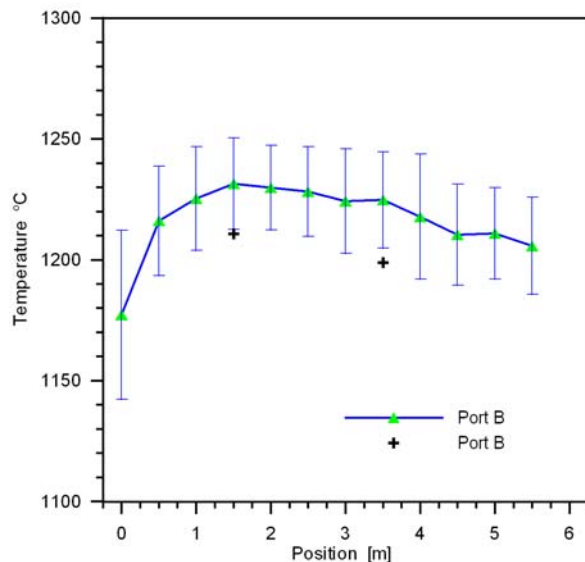
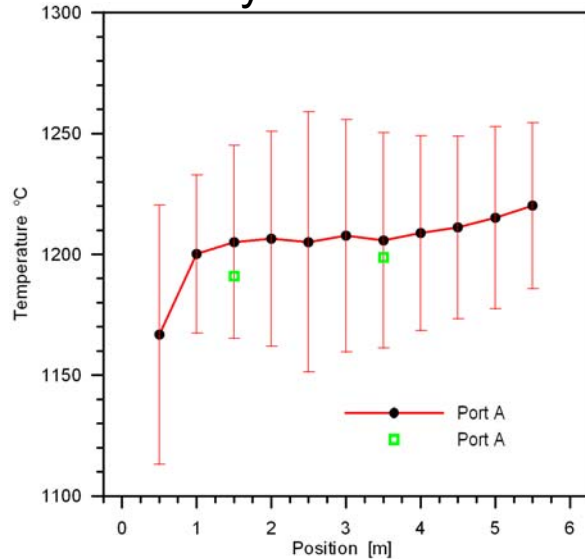


# CO Corrosion Wall



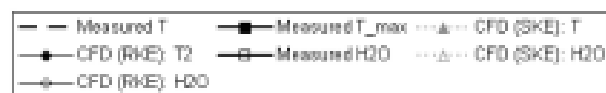
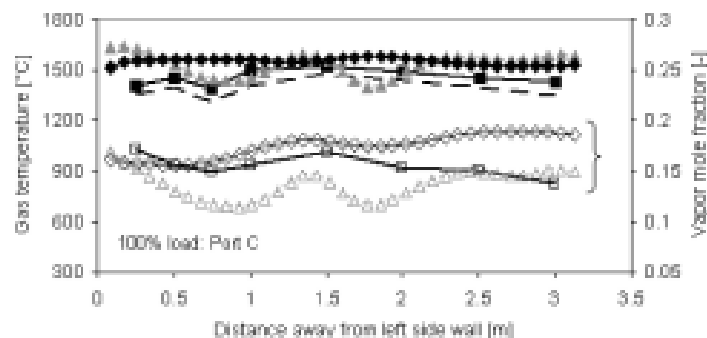
# Mixing of Flows

## Fynsværket

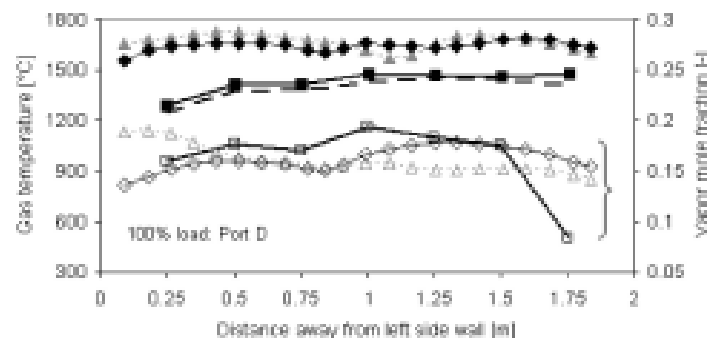


**MIXING COLD AND HOT  
AIR IS LIKE MIXING  
WATER AND OIL**

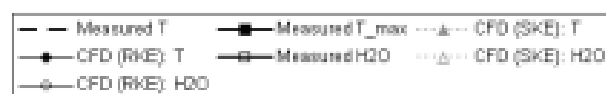
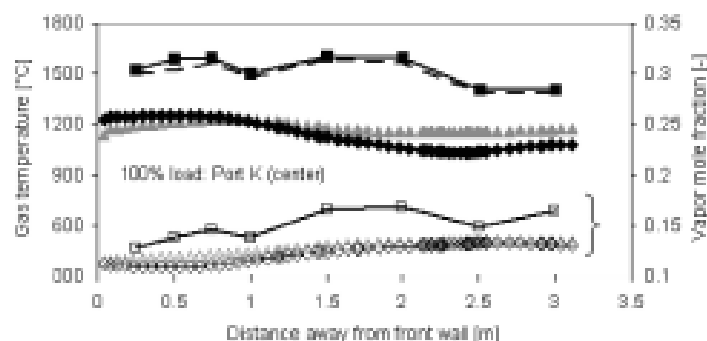
Pictures are recorded with  
10 ms between pictures  
and 333 $\mu$ s exposure time.



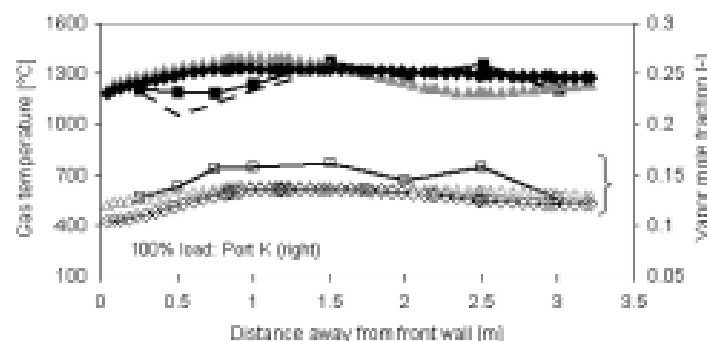
(a) At Port C



(b) At Port D

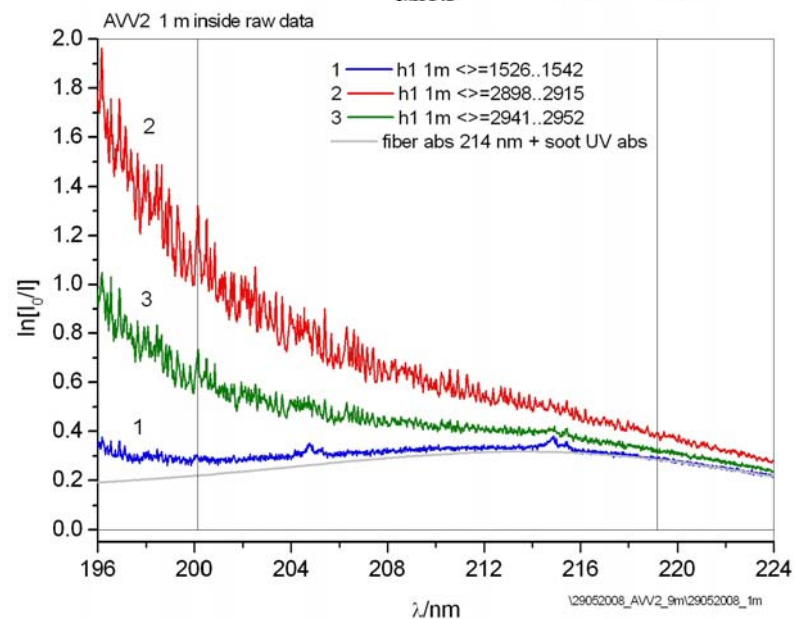
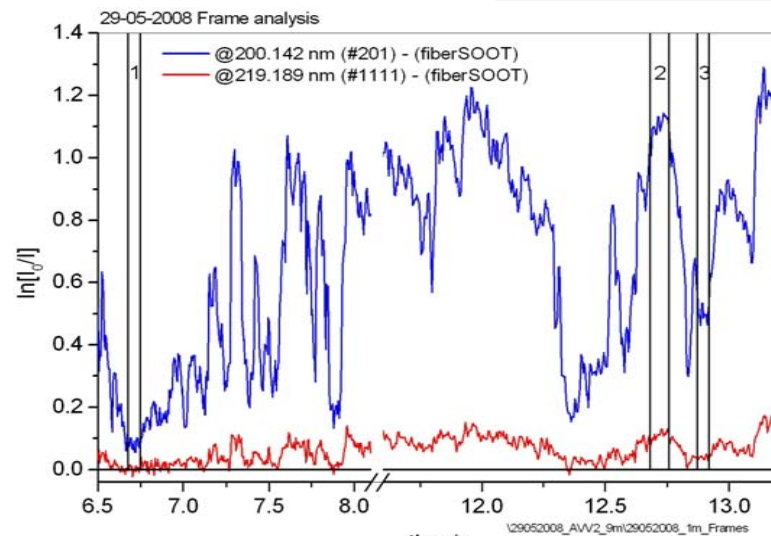
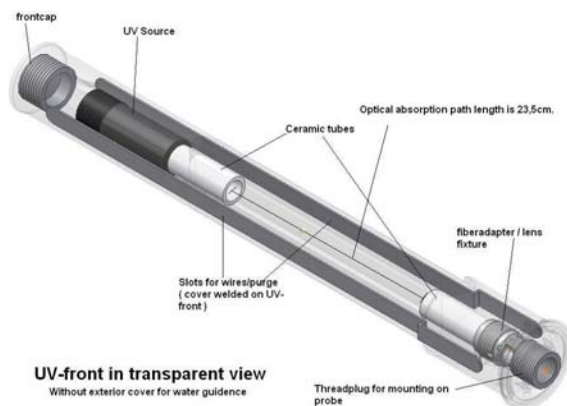


(c) At Port K (center)



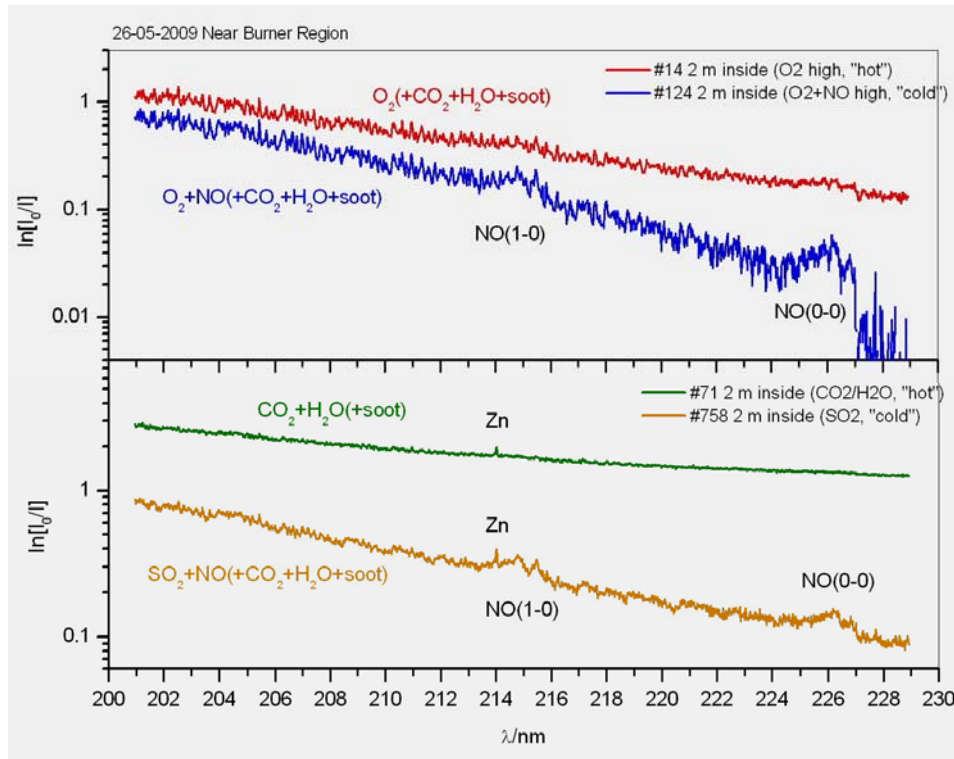
(d) At Port K (right)

Figure 11. CFD results vs FTIR measurements at four of the measuring ports at 100% load.





# Fast UV absorption measurements in Near Burner Region (coal)



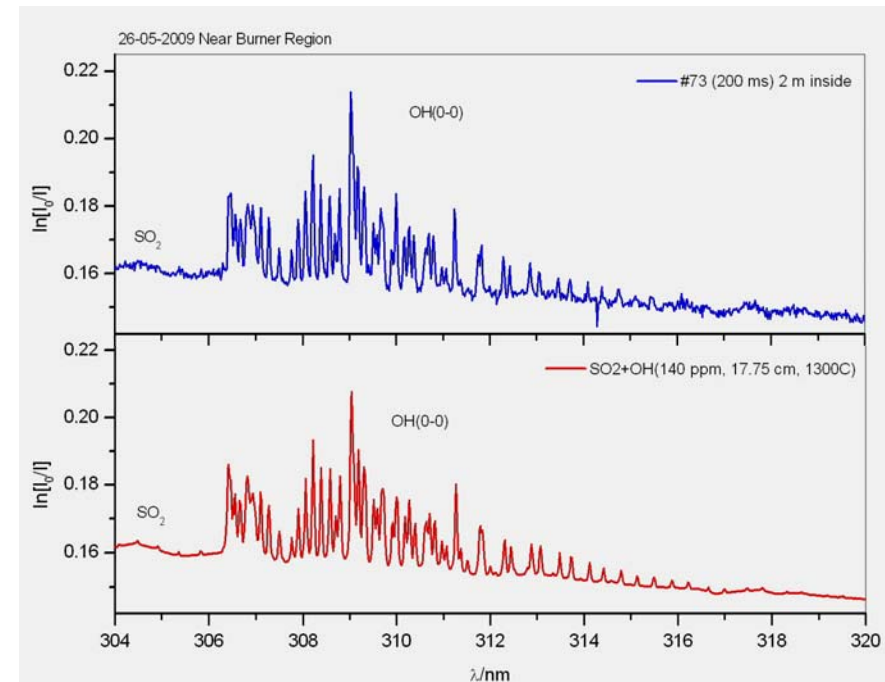
UV head (L up to 23.5 cm): 17.75 cm

1 ms exposure + 4.38 ms readout

in flame UV broad band absorption:

**T<sub>gas</sub>, NO, O<sub>2</sub>, SO<sub>2</sub>, H<sub>2</sub>O, CO<sub>2</sub>, OH, soot**

$$\ln \left[ \frac{I_0(\lambda)}{I(\lambda)} \right] = \sigma(\lambda, T) \cdot L \cdot [Gas]$$



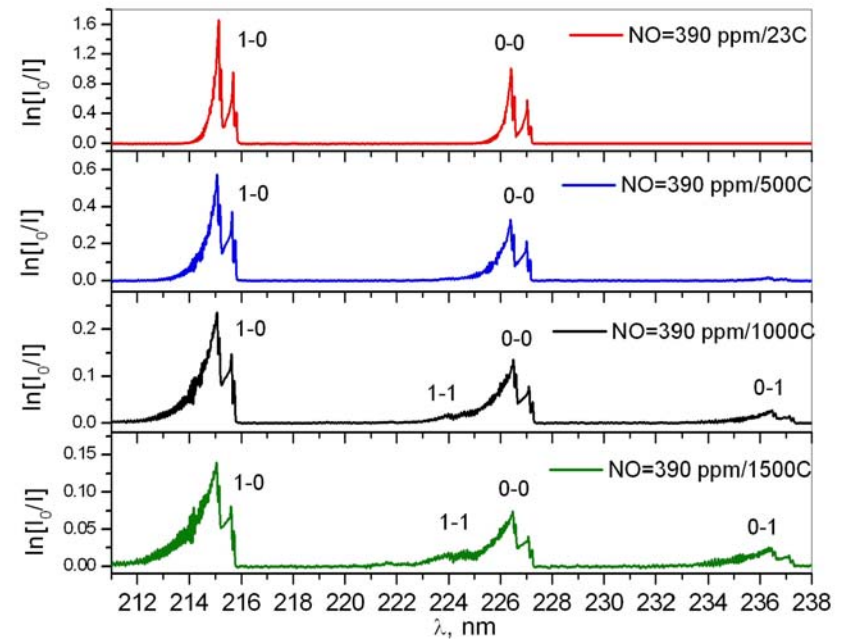
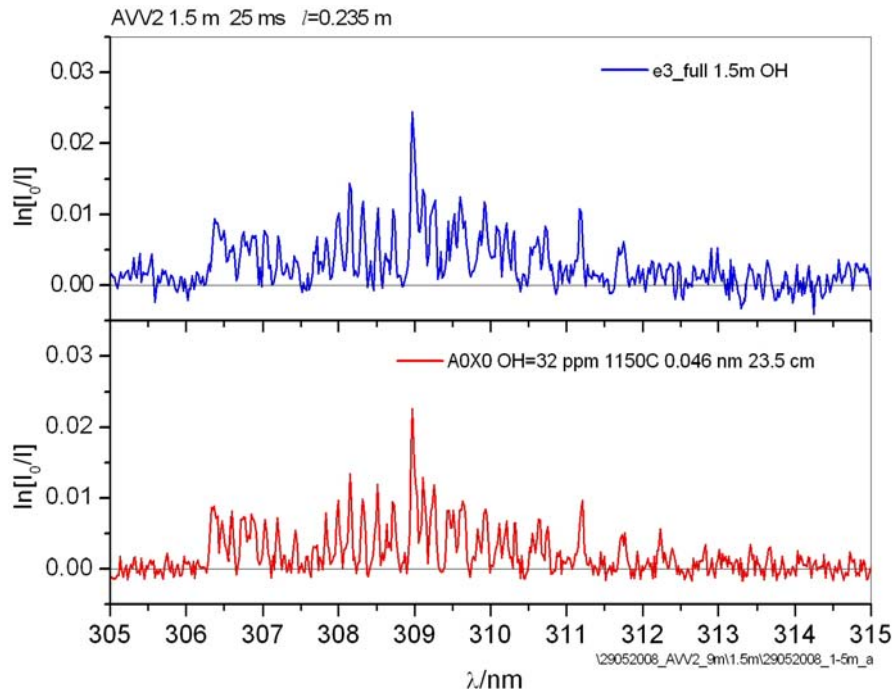


# HOT GAS FACILITY

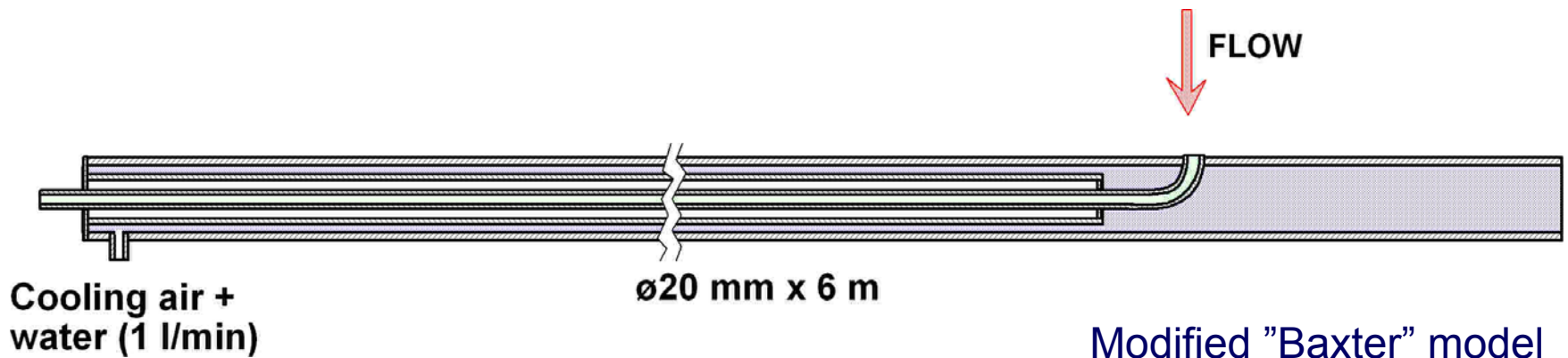
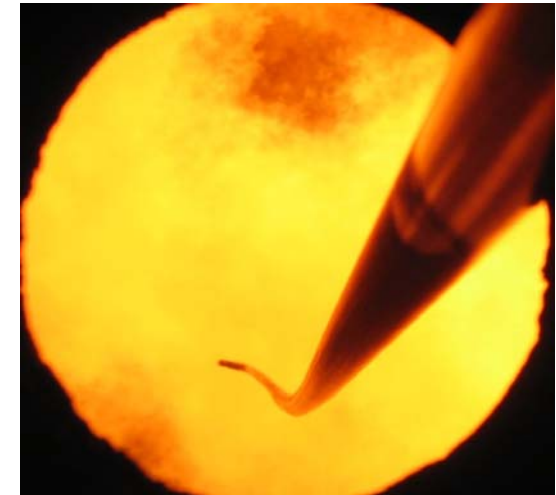


REFERENCE DATA  
optical properties of gases

VERIFICATION  
methods and results

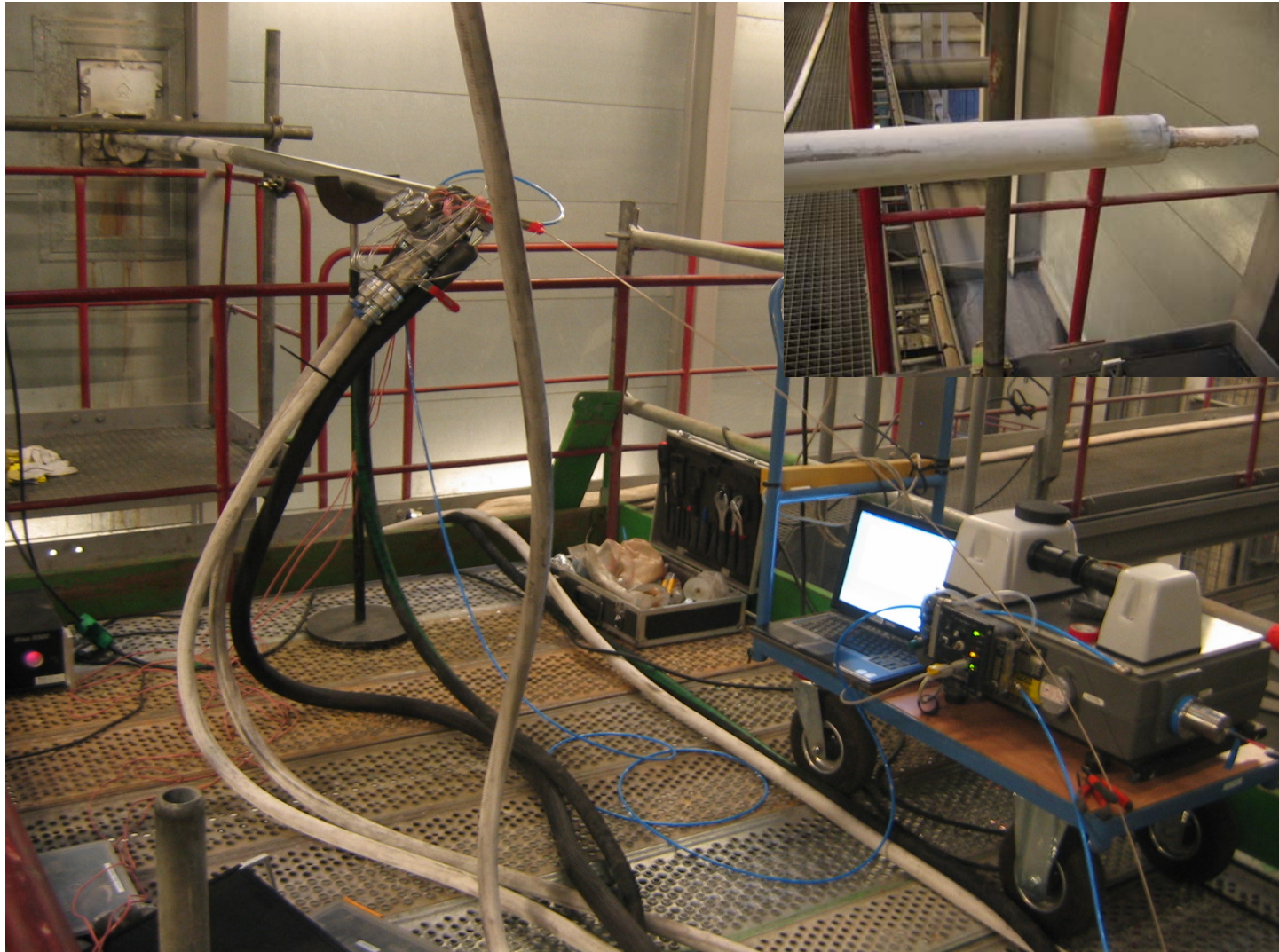


# Ekstraktive Flex Probe

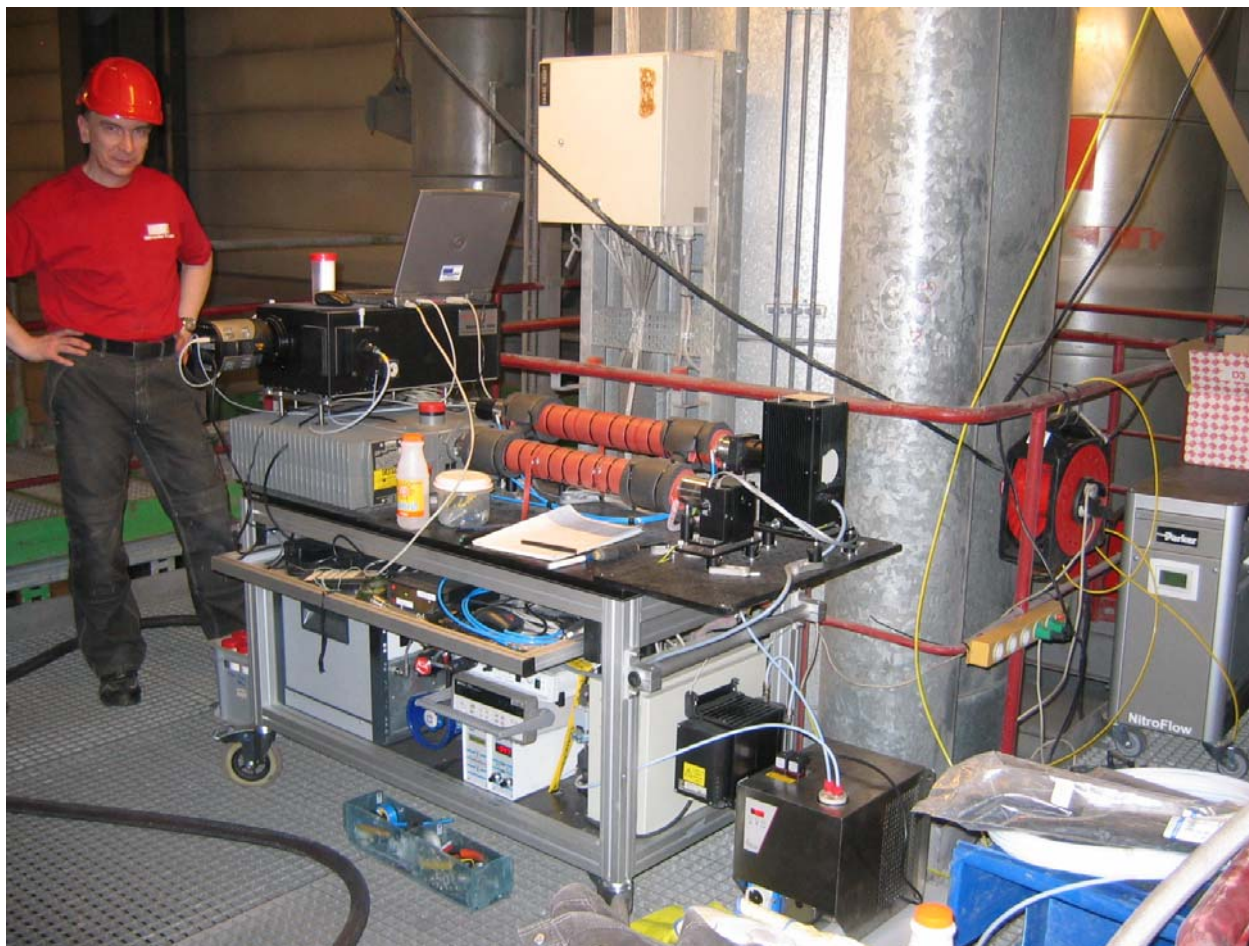




# 7 m probe Fynsværket



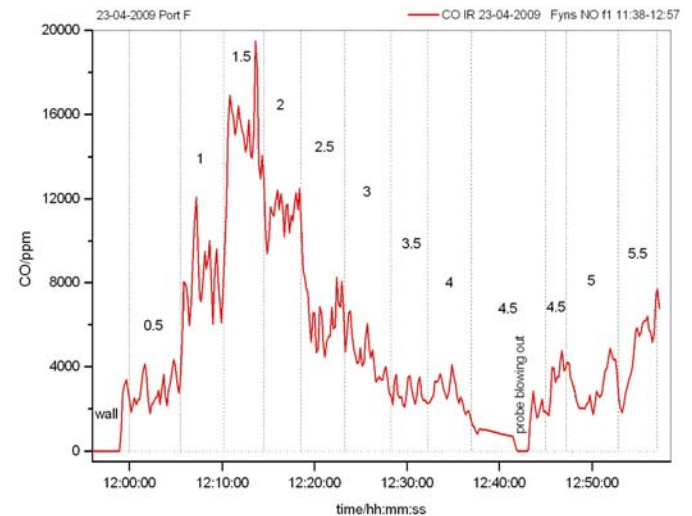
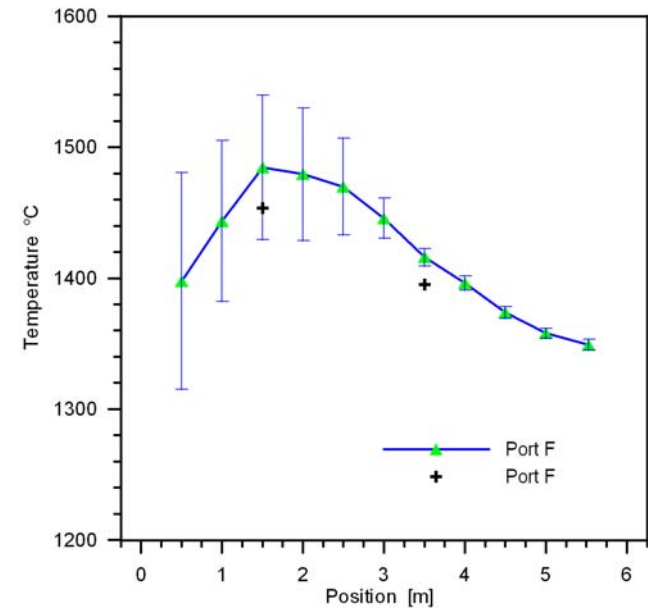
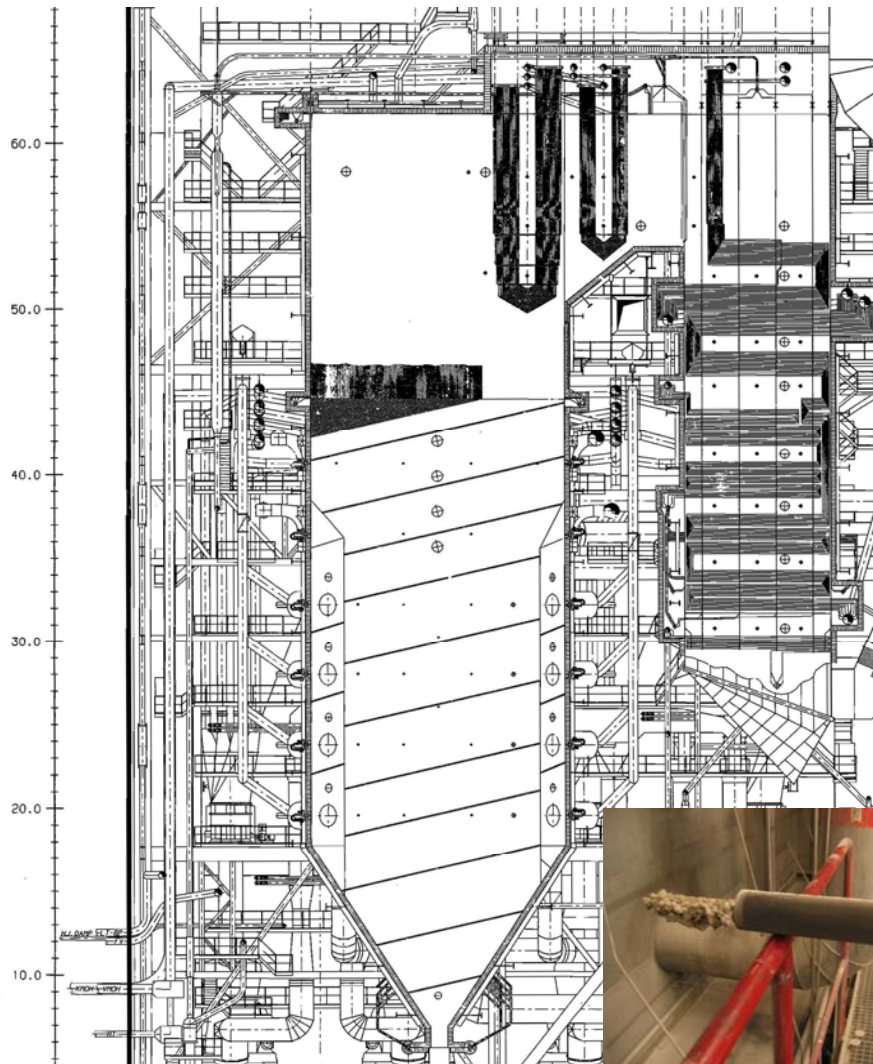
# Extrative FTIR - UV



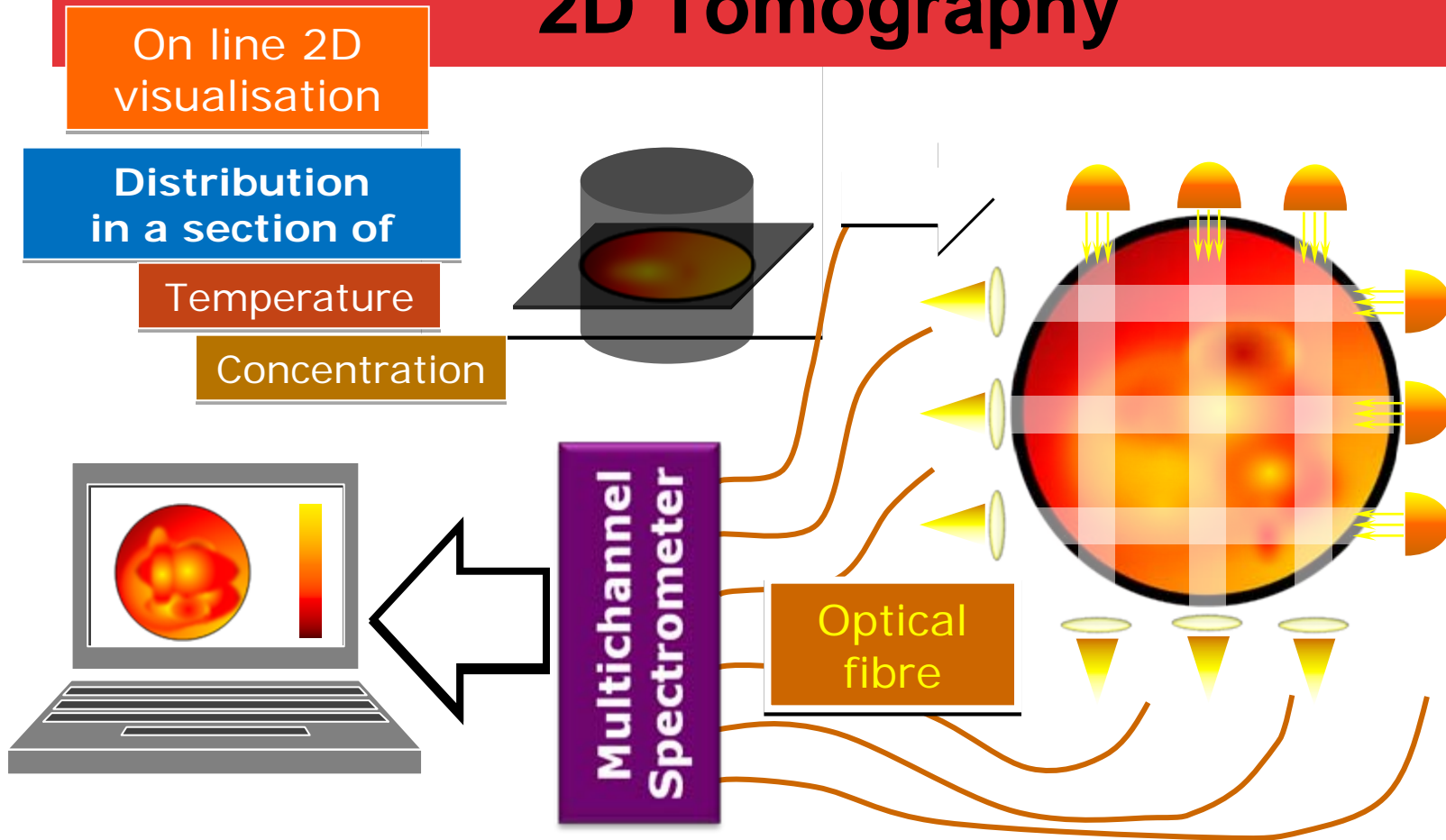


# FYN SVÆRKET

Apr. 2009



# New diagnostic tools: 2D Tomography



- 2D Tomography of e.g. hot gas inside of an exhaust pipe shows distribution of temperature or concentrations in a pipe section



# CONCLUSION



- IR and UV fiber-optics powerfull tool
- Measurements in boilers and flames
- Mixing of flows
- Sensors
  
- New gas components?

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